

2021 Chehalis ASRP

Lower Satsop River Habitat Restoration

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INTRODUCTION

The Lower Satsop River Habitat Restoration Project proposed by the Washington Department of Fish and Wildlife (WDFW) Restoration Division addresses habitat restoration of three off-channel ponds (**Figure 1**) in a phased experimental approach. Our goal with this experiment is to study amphibian and native fish responses to restoration treatments (shallow water creation, spoil piles/dike removal, and increased floodplain connectivity). The project aims to improve riverine connectivity and habitat in the floodplain and reduce agricultural soil bank erosion. Encompassing cumulatively about 5.5 ha (13.6 ac), the Satsop Ponds are located just east of the Satsop River (**Figure 1**) about 1.0 mi (1.6 km) upstream of the confluence with the Chehalis River (River Mile 20) in Grays Harbor.

To support this effort, as part of its contribution to a basin-wide Aquatic Species Restoration Plan (ASRP), the Aquatic Research Section of the WDFW Habitat Science Division engaged in monitoring this site beginning in March 2015. This monitoring, as reported here, extended through the 2015-2017 and the 2017-2019 biennia to document baseline conditions at the ponds prior to initiating restoration efforts in the 2019-2020 biennium. Our active post-restoration monitoring is will help adaptively inform future restoration efforts in the Chehalis Basin, including those that WDFW and other entities have identified for the upcoming 2021-2023 biennium.

METHODS

SATSOP RESTORATION SITE: The Satsop Restoration site has three permanent ponds (Ponds A, B, and C; **Figure 1**) that were created from gravel pits excavated for construction in the early 1970s. The gravel pit dikes and spoils produced approximately 160,000 yd³ (122,000 m³) of soil and were deposited in the floodplain (**Figure 1**). Additionally, 2,500 ft (762 m) of the east bank immediately upstream from the gravel pits was rip-rapped in 1972 to prevent the lateral migration of the Satsop River channel eastward into Keys Road. This channel migration had been occurring prior to 1972 (see **Figure 2**; 1938 vs 1970s and **Figures 3** and **4**). The combination of bank hardening and deposition of floodplain spoils has disconnected the Satsop River from its local floodplain, but channel migration has remained a competent process in much of the lower Satsop River mainstem as reflected in channel changes over the last 80 years (**Figures 3** and **4**). Additionally, there are a total of six ephemeral ponds at the site, five small ponds around Pond C (the easternmost permanent ponds) and a single ephemeral pond adjacent to Pond B (the centermost pond) (**Figure 5**). Pre-restoration monitoring at all sites began in 2015, restoration occurred in Pond C in 2019 and in Pond B in 2020, and Post-restoration monitoring began in Pond C in fall 2019 and Pond B in fall 2020.



Figure 1. Satsop Ponds Restoration Footprint. Lines approximate the current positions of the ponds, dikes and the spoils areas.

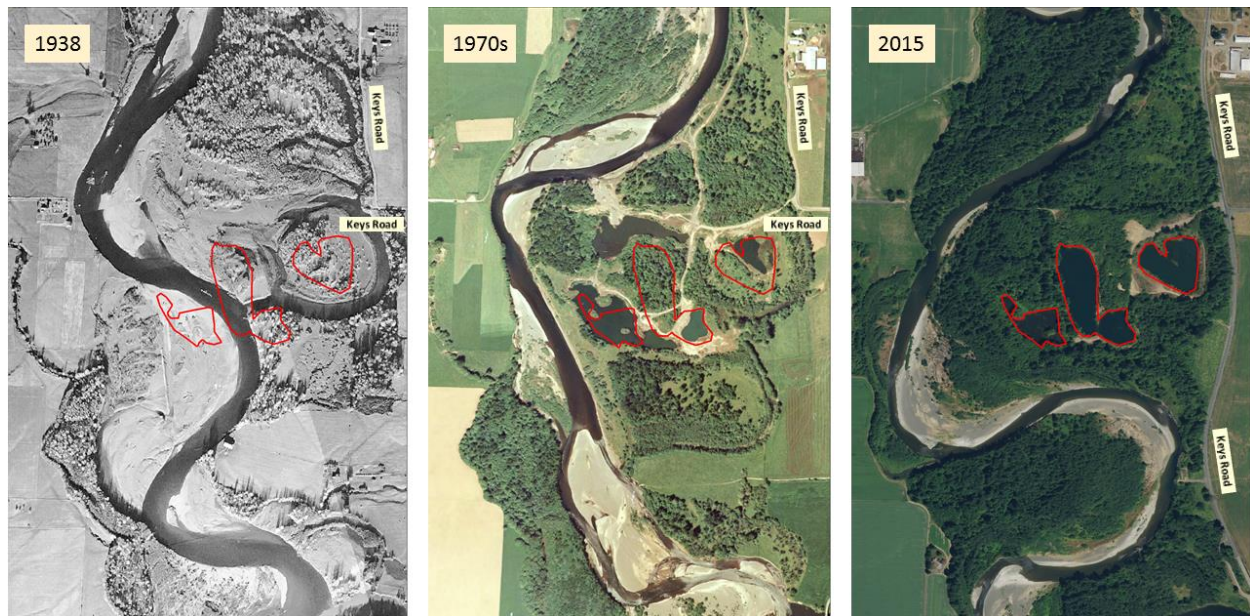


Figure 2. Satsop Ponds Restoration Site Aerial Photographs. Red outlines indicate current pond locations. Serial photographs show: 1) unrestricted floodplain migration of the Satsop River, old oxbows, and side channels in 1938; 2) rip-rapping of eastern river edges, pond excavation, and road development within the pond complex in the 1970s; and 3) active erosion of agricultural lands on west side of the river and straightening of Keys Road south to the bridge over the Chehalis River in 2015. The 1938 aerial photograph was taken in winter, whereas the 1970s and 2013 aerial photographs were taken in summer.

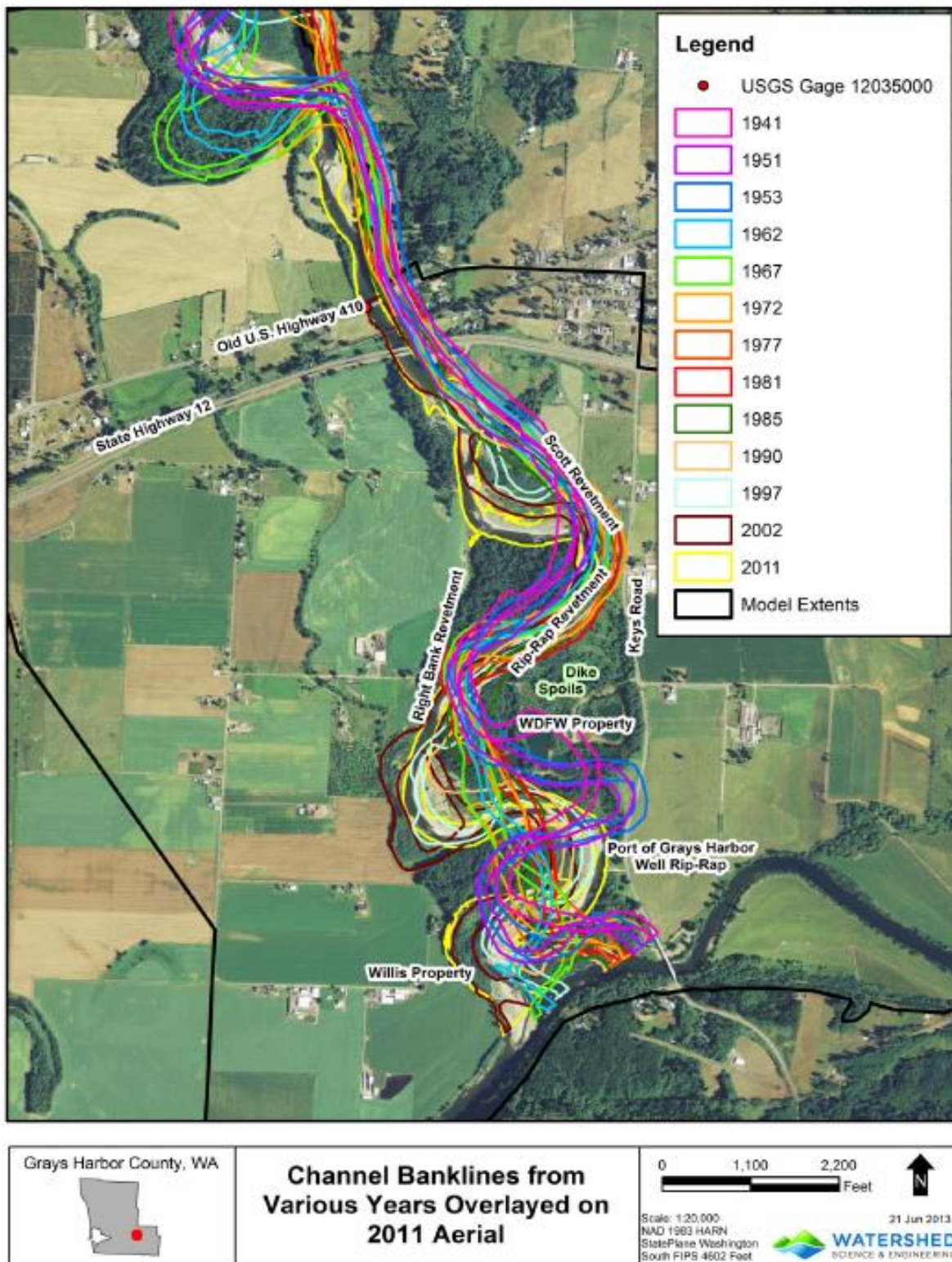


Figure 3. Satsop River Channel Migration 1941-2011. Adapted from the Satsop River Riprap Removal Restoration Project Report: Watershed Science & Engineering 2013.

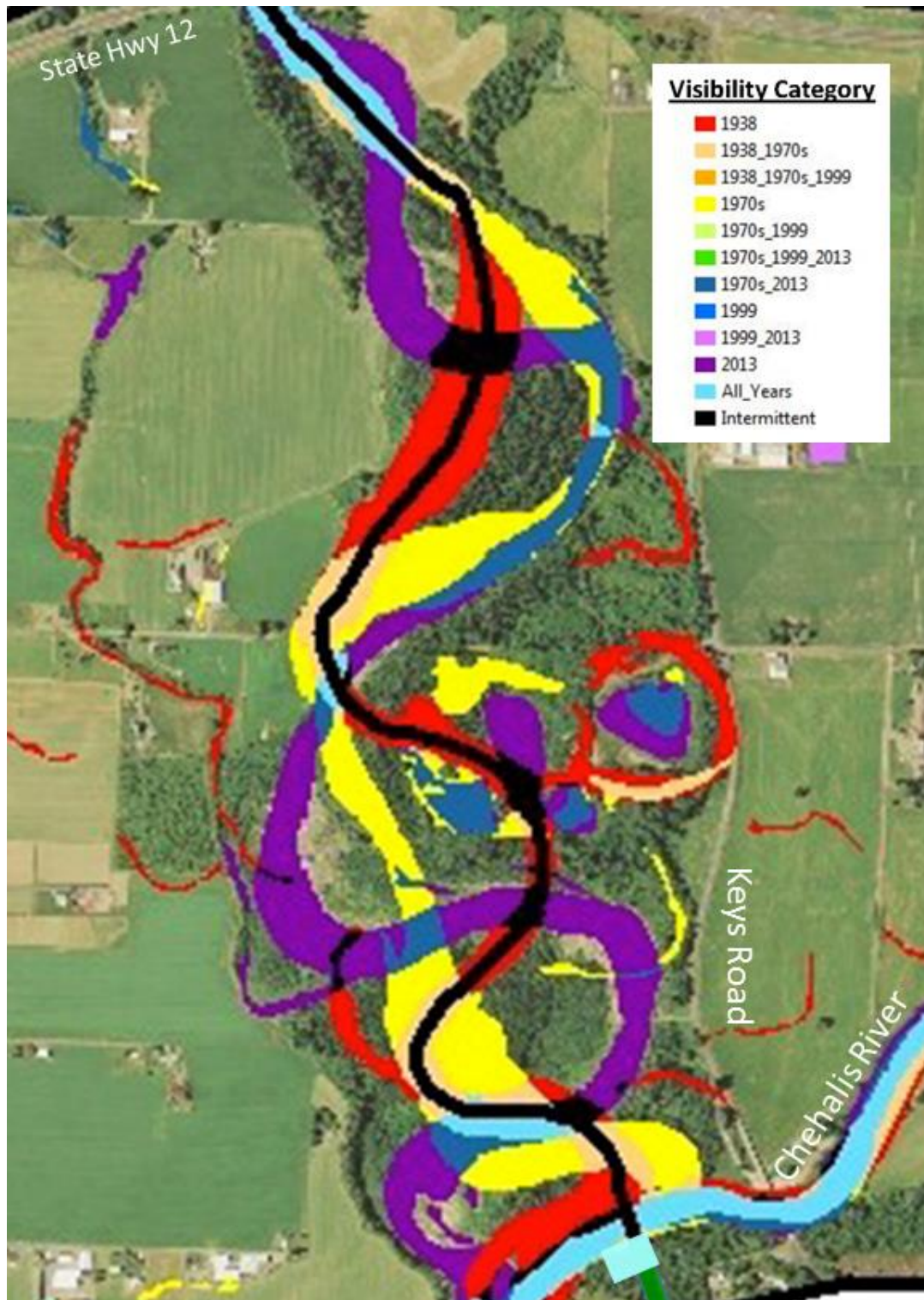


Figure 4. Channel Migration in the Satsop River near the Satsop Ponds Restoration Site. Adapted from Pierce et al (2017). Color scheme are visibility categories based on 1938, 1970s, 1999, and 2013 aerial photographs for different time periods. Background is the 2013 aerial photograph. The black upper and lower boundaries are the 100-year FEMA floodplain plus 100 meters; the black central line is the mid-point of the Satsop River main channel in 1938.



Figure 5. Temporary (Auxiliary) Ponds Associated with Permanent Pond C at the Satsop Restoration Sites. The five auxiliary ponds are the label small green-line polygons. Auxiliary Ponds encompass nearly all Long-Toed Salamander (*Ambystoma macrodactylum*) breeding and rearing habitat at the Satsop Restoration Sites.

OFF-CHANNEL RESTORATION ACTIONS

Phase 1: We commenced construction for restoration actions on Pond C during summer 2019 (**Figure 6**). These actions included excavating approximately half of the spoils pile and placing material into Pond C to shallow the margins on the North and West sides. All large trees removed from the spoils pile were placed in the ponds to provide shallow water habitat cover. The remaining small trees were placed in discrete piles in the floodplain for wildlife habitat. [**Note:** Pre-Post restoration comparison photos can be seen in the results section (**Figure 17**)].

We took care to recreate some of the lost auxiliary ponds for Long-toed Salamanders (*Ambystoma macrodactylum*) by creating compacted swales that would hold temporary water in winter. In winter 2020, in preparation for riparian plantings, a local farmer tilled this area including the water-filled ephemeral swales which had newly deposited Long-Toed Salamander eggs. This tilling in 2020 represented a total loss for those early-breeding salamanders. Furthermore, tilling altered the hydrology of these areas so they no longer sufficiently maintained water for salamander breeding. Because of this, we discussed all subsequent planting plans in advance to avoid any further damages to the temporary ponds. In late winter 2020, the Grays Harbor Conservation District with assistance from local volunteers planted roughly 7,000 riparian trees and shrubs as well as emergent wetland plants throughout the project site. Mulching was avoided in wet areas to prevent toxicity to amphibians due to the tannins within the mulch.

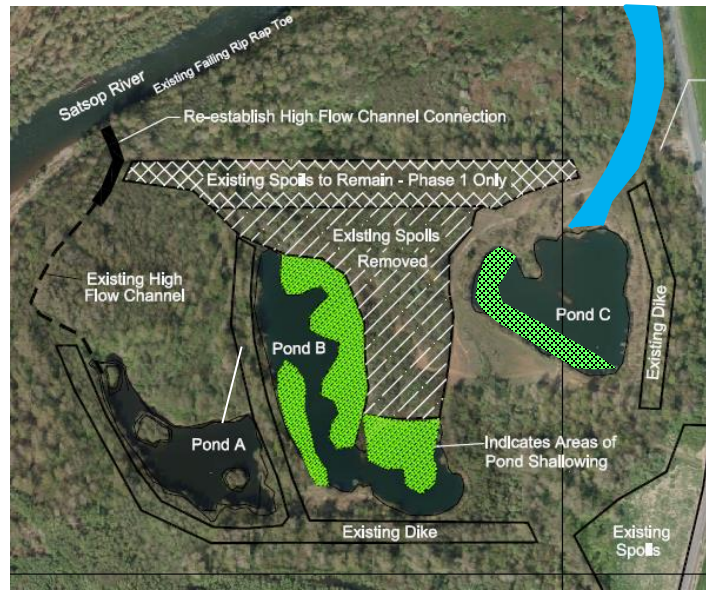


Figure 6. Phase 1 & 2 restoration activities. Green hatched areas are areas that have been shallowed and blue is new the new high-flow channel which engages the river to the north.

Phase 2: Beginning in June 2020, we initiated Phase 2 restoration to improve the hydrological connection for Ponds B by removing all remaining spoils and dikes (**Figure 7**). We used the removed spoil materials to shallow Pond B and create shallow water habitat ideal for amphibian breeding. [Note: Pre-Post restoration comparison photos can be seen in the results section (**Figure 18**)].

In addition to restoration around the ponds and dikes, we also removed rock toe and rip rap located north of Pond A and B along the Satsop River to allow increased bank erosion and engage historic channels that run to the ponds. This permitted increased reconnection and flood storage (see **Figure 6**: “existing failing rip rap toe” & **Figure 7**) into Pond B. Active flooding in winter 2020 has exposed more rip rap at this location that will be removed in summer 2021.



Figure 7. Rock toe and rip rap along the Satsop River, north of the ponds. A: Pre-removal. B: Active removal. C: Post-removal

In 2018 prior to any restoration actions, we noticed active channel scour on the north end of Pond C adjacent to Keys Road. This appears to have been caused by high flooding which eroded around rip rap on the north side of the site next to the road. This allowed waters to re-engage an old channel during extreme events, scouring into Pond C (**Figure 8**). This was the same year there was an avulsion event just downstream of our project site that disconnected an entire oxbow from the rest of the river.

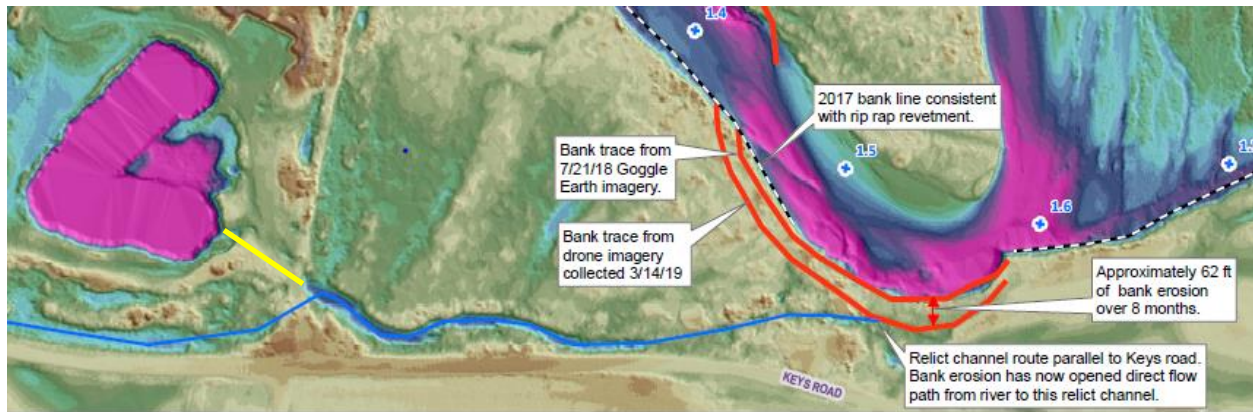


Figure 8. Pond C (in pink, left side) natural re-engagement with Satsop River due to rip rap erosion. High waters flowed around rip rap, engaged the relict channel, and moved out of channel to scour an access road (area in yellow) into Pond C.

Enhancing a connection from the upper end of Pond C was not initially part of our restoration plans but, because the river independently re-engaged, we decided to actively contribute to this ongoing process. Since the rip rap was rapidly failing, we took no action on the rip rap and constructed a high-flow channel at the road to convey flood flows from the Satsop River into pond C, providing an enhanced hydraulic connection and flushing flows (**Figure 9**).



Figure 9. January 2021 drone flight showing Phase 2 restoration activities to enhance hydraulic connection and overflow channel into Pond C fully engaged.

Winter 2020-2021 was the first high flow season after all completed restoration actions across the pond complex. The restoration site is fully functioning to absorb flood waters from the Satsop River for storage after our rip rap, dike, and spoils pile removals and active channel reengagement (**Figure 10**).



Figure 10. Drone flight of January 2021 high water event (DFW, Jane Atha). All ponds are connected to the river.

With both these phased restoration efforts, we anticipate a shift toward a greater range in stage, a generally lower seasonal water temperature profile, and potentially a generally higher seasonal dissolved oxygen profile. We expect that these physical shifts will promote greater native species composition and abundance, and a shift toward fewer exotic species or numbers. Our pre- and post-monitoring on a suite of aquatic or aquatic-associated vertebrates and will enable us to determine whether these restoration efforts favor native over exotic species.

In addition to ground-moving restoration, the Satsop River and this pond complex is invaded with Knotweed (**Figure 11**). Expanded efforts are ongoing in the basin by many different entities coordinating through the Satsop Knotweed Cooperative Weed Management Area. Given our new intensive restoration efforts, we needed to treat the ponds and adjacent riverbanks for Knotweed, as well as for Scotch Broom and Blackberry to minimize spread into the newly-restored area. WDFW, led by Dave Heimer, began treating Knotweed at the Satsop Ponds using a Marshmaster with a spray tank to gain access to Knotweed located on the gravel bars to the south and scattered throughout the forest that bordered the river (**Figure 11**). Knotweed was found in patches at varying densities throughout the project site, except for the Planting Area, which consisted of mostly blackberry and Scotch Broom. In total, 5.11 acres of Knotweed and 0.31 acres of Scotch Broom and blackberries were sprayed (**Figure 12**).

Knotweed removals were largely successful in 2020 (**Figure 13**). Areas that were treated in 2020 will be resurveyed and regrowth or skips will be treated (**Figure 14**). In addition, we estimate there is knotweed in the North Woods (3 acres), South Woods (11 acres) and Gravel Bar (>1 acre) that will require an initial treatment in 2021 and a subsequent follow up the following season.



Figure 11. Untreated knotweed growing along and into the forest edge adjacent to the southern gravel bar and in the woods adjacent to the ponds.

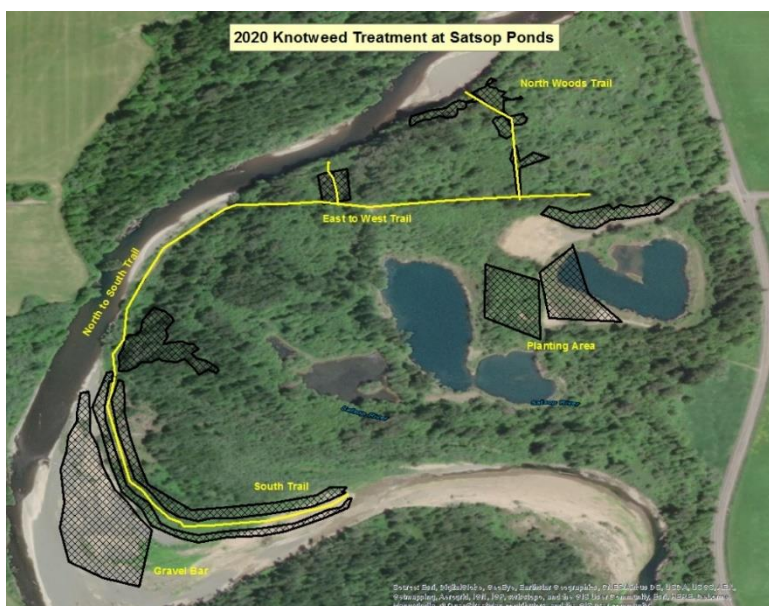


Figure 12. A map 2020 weed treatment areas and trails for access at the Satsop site



Figure 13. Knotweed on the South Trail near the gravel bar on 10/12/20 during treatment and on a revisit on 11/1/20



Figure 14. *Regrowth of sprayed Knotweed seen in 2021*

OFF-CHANNEL HABITAT MONITORING: This restoration project was designed as a monitored experimental effort to inform its value to the native aquatic biota. The Pre-restoration monitoring phase occurred from 2015 to 2019 for Pond C and 2015 to 2020 for Pond B and was intended to establish baseline information on the existing biota that will provide a temporal reference (control) site against which restoration efforts can effectively be compared; this is the focus of this report.

Monitoring for focal amphibians was conducted using a combination of egg mass (EM) and off-channel extensive surveys (OE). We used visual encounter surveys for EM as these are the most common and effective way to monitor the presence and breeding abundance of many amphibian species, especially those found in stillwater. We conducted EM surveys at water depths of up to 1 m (3 ft) in the focal footprint. We supplemented visual encounter with dip net sampling to understand what fishes were present at the time amphibian egg masses were deposited. In dip net sampling, we obtained 50 samples in each of the three permanent ponds, and up to 10 dipnet samples in each of the auxiliary ponds. In some cases, auxiliary ponds were too small to accommodate 10 dipnet samples. Because dipnet sampling efficiency can be limited for some fishes, we added one electrofishing survey to the EM effort starting in 2016. The electrofishing survey involved a two-hour survey (including processing) of the focal footprint. We used inflatable kayaks to facilitate access to the entire footprint of the permanent ponds. For all aquatic vertebrates encountered, we recorded the identity and life stage of all species.

OE surveys were conducted exclusively in the permanent ponds. The OE surveys were designed primarily for fishes and turtles, but also detected American Bullfrog, because of their increased activity in late spring-summer. We conducted OE surveys over a two-day interval at each site. Surveys involved 10 evenly spaced vegetation transects (spacing was a minimum of least 5 m apart), at which vegetation composition, percent cover, water temperatures, deepest depth, visibility, wetted widths, and distance between transects were recorded. Animal sampling involve dip net surveys (25 dipnet samples/pond), minnow traps (3 traps/transect for a total of 30/pond) and up to 4 fyke nets (2 fish and 2 turtle) per site (we always placed a minimum of 1 fish and 1 turtle net). All traps were placed on the first sampling day, left overnight and retrieved the next day and their captured animals processed and released. One

electrofishing survey identical to that performed for the EM surveys was added to each extensive survey beginning in June 2016.

We recorded incidental observations on other highly aquatic species like American Beaver (*Castor canadensis*) or predatory mammals like River Otter (*Lontra canadensis*). Observations of these species include direct observations of animals or various observations of sign such as lodges, dams, dens, scent mounds, chews, or middens. We did not systematically record aquatic invertebrates. However, we recorded several prominent aquatic invertebrates incidentally during our surveys. We also recorded birds at the site Pre-Restoration but have reported these data previously.

We also established two or three photopoint stations around each permanent pond to photo archive gross water level, vegetation, and habitat changes (**Figure 15** and **Appendix Table 1**). These stations were placed in locations that should allow monitoring during and Post-restoration. At each photopoint, photographs were taken at 30° increments covering the wetted area, resulting in 5-12 photographs per photo-point location depending on whether the wetted area was circumferential or something less.

We also conducted snorkel surveys on the mainstem Satsop River to identify instream aquatic biota in late summer during low flows to understand the extent biotic exchange between the river and off-channel ponds (data in **Supplemental Study**).



Figure 15. Photopoint Locations at the Satsop Ponds Restoration Site. White dots show photopoint locations. Alphanumeric photopoint labels matches information in **Appendix Table 1**.

RESULTS

Our focal sampling to date involved 32 total surveys, 23 of which were conducted prior to any restoration work from 12 March 2015 to 12-17 June, 2019. Based on survey type, this included 15 EM, 8 OE, and 11 Electrofishing (EF) for Pre-restoration monitoring of Pond C. Pre-restoration survey counts for Pond B includes 18 EM, 10 OE, and 14 Electrofishing (EF) surveys through June 2020. In addition, the Wildlife Program conducted 13 days of ground-based waterfowl and waterbird surveys from 10 November, 2015 to 13 April, 2016. One snorkel survey on the Satsop River was completed on 14 September, 2016. Post-restoration surveys for Pond C involved 9 separate surveys, including 6 EM, 3 OE, and 5 EF surveys. Post-restoration surveys for Pond B include 3 EM, 1 OE, and 2 EF surveys to date. A comprehensive bird survey was conducted on 16 June 2020 by Wesley Bowens.

Considerable variability existed in focal aquatic habitats surveyed, which included three permanent and up to six temporary ponds (depending on year). Among the three permanent ponds, Pond B consistently had the largest footprint, Pond A was consistently smallest, and Pond C was consistently intermediate in size between the other two. However, Pond B was the most variable of the three ponds in size, increasing by as much as 49% or 13,061 m² (1.31 ha [0.91 ac]), Pond A was intermediate in size variability, increasing by as much as 35% or 3,601 m² (0.31 ha [0.76 ac]), and Pond C was the least variable in size, increasing by as much as 11% or 1,798 m² (0.31 ha [0.76 ac]). High variability in Pond B reflected the seasonal exposure to shallow shelves, especially on its east and southeast side and lobe (see **Figures 1 and 6**). Permanent ponds had their maximum surface areas in December or January of the water years (October-September) sampled. Depending on their size, temporary ponds were dry by April, May or June of any water year. Variability in drying between years was evident. For example, the smallest temporary pond, Dirt Mound, was dry in April of the 2015-2016 water year, but was still wet in April of the 2016-2018 water year. During the 2018 sampling season, a new temporary pond (Beaver Lodge Road Pond) next to the largest permanent pond B, was found to have egg masses and was subsequently sampled.

During the 2019 sampling season, restoration began to remove the spoils between ponds B and C. The spoil was placed on the west side of Pond C to shallow out the edges. This restoration event took place between the June and September surveys. The addition of the spoil to Pond C made for less visibility on the west side of the pond where the spoil was added. It is possible that this restoration may bias results for the final extensive survey.

We observed at least 27 species of amphibians and fishes in the Satsop Pond complex over the entire Pre- and Post-Restoration survey period (**Tables 1 and 2, Appendix Tables 2-7**). Of the 27 species, 18 were native, nine were non-native, seven were amphibians and 20 were fishes. Of the seven amphibian species, six were native: Northwestern Salamander (*Ambystoma gracile*), Long-Toed salamander (*Ambystoma macrodactylum*), Pacific Treefrog (*Pseudacris = Hyla regilla*), Northern Red-Legged Frog (*Rana aurora*), Roughskin Newt (*Taricha granulosa*), and Western Toad (*Bufo = Anaxyrus boreas*). The seventh amphibian species was the non-native American Bullfrog (*Rana catesbeiana*). Of the 20 fish species, 12 were native: Chum Salmon (*Oncorhynchus keta*), Largescale Sucker (*Catostomus macrocheilus*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Olympic Mudminnow (*Novumbra hubbsi*), Pacific Lamprey (*Entosphenus tridentatus*), Prickly Sculpin (*Cottus asper*), Rainbow/Steelhead Trout (*Oncorhynchus mykiss*), Redside Shiner (*Richardsonius balteatus*), Riffle/Reticulate Sculpin (*C. gulosus/perplexus*), Speckled Dace (*Rhinichthys osculus*), Three-Spined Stickleback (*Gasterosteus aculeatus*), and Torrent Sculpin (*C.*

rhotheus). The remaining eight species were non-native: Black Crappie (*Pomoxis nigromaculatus*), Bluegill (*Lepomis macrochirus*), Brown Bullhead (*Ameiurus nebulosus*), Common Carp (*Cyprinus carpio*), Largemouth Bass (*Micropterus salmoides*), Pumpkinseed (*Lepomis gibbosus*), Rock Bass (*Ambloplites rupestris*) and Yellow Perch (*Perca flavescens*).

Amphibian and fish occupancy and richness between the three permanent and six temporary ponds were asymmetric. Of the 27 amphibians and fishes recorded to date, all were recorded in at least one permanent pond, whereas only seven of the 27 species (four amphibians and three fishes) were recorded in the temporary ponds (**Tables 1 and 2, Appendix Tables 2-7**). No amphibian or fish species was recorded exclusively in the temporary ponds. Over the entire study interval to date, overall amphibian and fish species richness was at least 18 in all three permanent ponds, but four or fewer in each temporary pond. Amphibian and fish occupancy and richness also showed marked temporal and spatial variability. Based on all amphibian and fish species combined, species richness was consistently greatest in Pond B.

Though permanent ponds were richest in amphibian species, we detected only modest numbers of both native amphibians and native amphibian development stages (egg masses/embryos and larvae) in the permanent ponds. In contrast, we recorded all life stages of the exotic American Bullfrog in all surveys across all water years. Larval American Bullfrog numbers, which were prominent in general, were consistently higher in Pond A than in the other two permanent ponds.

Native amphibian use of temporary ponds was prominent. Overall abundances of Long-toed Salamander life stages were over two orders of magnitude higher in temporary ponds than in permanent ponds; and overall observation of Pacific Treefrogs were at least seven times as frequent in temporary ponds as in permanent ponds. Two other amphibian species were found in temporary ponds; however, no eggs were found of the two in the temporary ponds. One was an adult Roughskin newt found on a single survey date in South Pond, the only temporary pond in which native amphibians were not recorded using for reproduction. Northern Red-Legged Frog larvae were found in West pond and South pond on a single survey date, though no Red-Legged Frog egg masses were recorded for either of those ponds. A juvenile Northern Red-legged Frog was also found in North Pond as well as the Beaver Lodge Road pond associated with pond B. The abundance of these amphibians likely reflects the relatively lower diversity and abundance of predatory fishes in temporary ponds.

Table 1. Pre-Restoration Occurrence and Richness Summary across 2015-2019 Surveys.

Taxa		Species Occurrence and Richness									
		Entire Complex	Permanent Ponds			Temporary Ponds					
			A	B	C	Dirt Mound	East	North	South	West	B pond beaver
Native Amphibians		6	3	6	5	1	3	3	2	3	3
Long-toed salamander			—	x	x	x	x	x	—	x	x
Northwestern salamander			x	x	x	—	—	—	—	—	x
Northern red-legged frog			x	x	x	—	—	x	x	x	x
Pacific treefrog			—	x	x	—	x	x	—	x	—
Roughskin newt			x	x	x	—	x	—	x	—	—
Western toad			—	x	—	—	—	—	—	—	—
Non-Native Amphibians		1	1	1	1	0	0	0	0	0	0
American bullfrog			x	x	x	—	—	—	—	—	—
Native Fish		12	10	11	8	0	0	0	3	0	0
Chum salmon			x	—	—	—	—	—	x	—	—
Largescale sucker			x	x	x	—	—	—	—	—	—
Northern pikeminnow			x	x	x	—	—	—	x	—	—
Olympic mudminnow			x	x	—	—	—	—	—	—	—
Pacific lamprey			x	x	x	—	—	—	—	—	—
Prickly sculpin			x	x	x	—	—	—	—	—	—
Rainbow/Steelhead trout			—	x	—	—	—	—	—	—	—
Redside shiner			x	x	x	—	—	—	x	—	—
Riffle/Reticulate sculpin			x	x	—	—	—	—	—	—	—
Speckled dace			x	x	x	—	—	—	—	—	—
Three-spined stickleback			x	x	x	—	—	—	—	—	—
Torrent sculpin			—	x	x	—	—	—	—	—	—
Non-Native Fish		8	4	6	5	0	0	0	0	0	0
Black crappie			—	x	x	—	—	—	—	—	—
Bluegill			x	x	x	—	—	—	—	—	—
Brown bullhead			x	—	—	—	—	—	—	—	—
Common carp			—	x	—	—	—	—	—	—	—
Largemouth bass			—	—	x	—	—	—	—	—	—
Pumpkinseed			x	x	x	—	—	—	—	—	—
Rock bass			x	x	x	—	—	—	—	—	—
Yellow perch			—	x	—	—	—	—	—	—	—
Grand Totals	Native	18	13	17	13	1	3	3	5	2	3
	Non-Native	9	5	7	6	0	0	0	0	0	0
	Overall	27	18	24	19	1	3	3	5	2	3

Table 2. Post-Restoration Occurrence and Richness Summary from 2020-2021 Surveys.

Taxa		Species Occurrence and Richness												
		Entire Complex	Permanent Ponds			Temporary Ponds								
			A	B	C	Dirt Mound	East	North	Tire rut South	Tire rut West	B pond beaver	Beaver lodge rd.	Dirt Mound 2	Southwest pond B
Native Amphibians		5	3	3	4	2	4	1	0	1	0	1	3	0
Long-toed salamander			—	—	X	X	X	X	—	X	—	X	X	—
Northwestern salamander			X	X	X	—	X	—	—	—	—	—	X	—
Northern red-legged frog			X	—	X	—	X	—	—	—	—	—	—	—
Pacific treefrog			—	X	—	—	—	—	—	—	—	—	—	—
Roughskin newt			X	X	X	X	X	—	—	—	—	—	X	—
Western toad			—	—	—	—	—	—	—	—	—	—	—	—
Non-Native Amphibians		1	1	1	1	0	0	1	0	0	0	1	1	0
American bullfrog			X	X	X			X				X	X	
Native Fish		8	5	7	7	0	0	0	0	0	0	0	0	0
Chum salmon														
Coho Salmon				X										
Lamprey Spp.			X		X									
Largescale sucker			X	X	X									
Northern pikeminnow			X	X	X									
Olympic mudminnow														
Rainbow/Steelhead trout														
Redside shiner			X	X	X									
Sculpin SP			X	X	X									
Speckled dace				X	X									
Three-spined stickleback				X	X									
Torrent sculpin														
Non-Native Fish		4	3	4	4	0	0	0	0	0	0	0	0	0
Black crappie														
Bluegill			X	X	X									
Brown bullhead			X	X	X									
Common carp														
Largemouth bass														
Pumpkinseed			X	X	X									
Rock bass				X	X									
Yellow perch														
Grand Totals	Native	13	8	10	11	2	4	1	0	1	0	1	3	0
	Non-Native	5	4	5	5	0	0	0	0	0	0	1	1	0
	Overall	18	12	15	16	2	4	1	0	1	0	1	4	0

Five taxa (Northern Pikeminnow, Olympic Mudminnow, Redside Shiner, Speckled Dace, and sculpins) comprised most observations of native fishes in the permanent ponds. Over half of these observations were sculpins which are represented by at least two species (Prickly and Torrent Sculpins). A third sculpin, the Riffle/Reticulate sculpin (*Cottus gulosus/perplexus*) complex was also present. Prickly Sculpins represent the majority (>90%) of identified sculpin samples, whereas only five and two individuals, respectively, have been identified as Torrent and Riffle/Reticulate complex sculpins. Notably, most observations of Northern Pikeminnow, Redside Shiner, and Speckled dace were recorded in Pond A, whereas the majority of observations of Olympic Mudminnow and sculpins were recorded in Ponds B and C. Besides the five dominant taxa, we recorded at least five additional species (Chum salmon, Largescale Sucker, Pacific Lamprey, Rainbow/Steelhead Trout,¹ Three-spined stickleback). Most Three-spined Stickleback and Lamprey were recorded from Pond A, most Largescale Sucker were recorded in Ponds B and C. At least seven native fish species (Largescale sucker, Northern pikeminnow, Pacific Lamprey, Prickly sculpin, Olympic Mudminnow, Redside shiner, and Three-spined stickleback) were recorded in all three ponds. Lampreys were the only native fish taxon recorded exclusively with electrofishing.

The eight non-native fishes in the Satsop pond complex were recorded exclusively in the three permanent ponds. Three centrarchid fishes (Bluegill, Pumpkinseed, and Rock Bass) dominated the non-native assemblage, and all three species were found in all three permanent ponds. Bluegill appear to be the dominant species across all three ponds with Pumpkinseed second, though we are not testing for hybrids, it has been recorded elsewhere². The remaining five species were each found in one pond and except for the Brown Bullhead recorded on 27-29 June 2017 were at low densities; these five species were Brown Bullhead in Pond A, Yellow Perch and Common Carp in Pond B, and Black Crappie and Largemouth Bass in Pond C.

The few fishes we recorded in the temporary ponds were found in one pond (South Pond) on only one date (24 February 2016). The species (and numbers) recorded on that date were Chum Salmon (n = 1), Northern pikeminnow (n=13), and Redside Shiner (n=55). The South Pond is also the only temporary pond in which Long-toed salamander and Pacific treefrog did not use for reproduction.

Besides amphibians and fishes, we recorded seven other aquatic and semi-aquatic animal taxa in the permanent ponds. Among these were four vertebrates, three native species (American Beaver, Raccoon [*Procyon lotor*], and River Otter); and the exotic Red-eared Slider Turtle (*Trachemys scripta*). Branch or stump chews, scent mounds, or slides of American Beaver were recorded at each of the permanent ponds; a large lodge was present on the northeast margin of the southeast lobe of Pond B; and at least two older bank lodges were observed in Pond A. We observed either River Otter directly or its sign (either middens or slides) in each of the permanent ponds, and one adult Red-Eared Slider was trapped on Pond B in September 2016. We also recorded three notable aquatic invertebrates. We found both the non-native Asian Clam (*Corbicula fluminea*) and at least one species of native freshwater mussel Floater Mussel (*Anodonta* spp.) in Ponds B and C; and the large jelly-disc colonies of the invasive filter-feeding Magnificent bryozoan, *Pectinatella magnifica*, in Ponds A and C.

¹ The Rainbow/Steelhead trout observed were a school of 30 observed in Pond B in May 2015. These fish were not captured, and we only observed them briefly when they swam by.

² Bluegill and Pumpkinseed are known to hybridize (Ballantyne and Colgan 1978).

Post-restoration results:

To date we have performed 14 Post-Restoration surveys (6 EM, 3 OE, and 5 EF) from 24 September 2019 to 5 April 2021. We observed at least 18 species of amphibians and fishes; thirteen were native, five were non-native, six were amphibians, and twelve were fishes. Of the six amphibian species, five were native: Northwestern Salamander, Long-Toed Salamander, Pacific Treefrog, Northern Red-Legged Frog, and Roughskin Newt. The sixth species was the non-native American Bullfrog. Of the twelve fish species, eight were native: Coho Salmon, Largescale Sucker, Northern Pikeminnow, lamprey sp., sculpin sp., Redsided Shiner, Speckled Dace and Three-spined Stickleback. The remaining four fish species were non-native: Bluegill, Brown Bullhead, Pumpkinseed, Rock Bass.

Amphibian and fish occupancy and richness between the three permanent and six temporary ponds were asymmetric. Of the eighteen amphibian and fish species recorded to date, all were recorded in at least one permanent pond, whereas only native amphibians were recorded in the temporary ponds Post-Restoration. In addition, we detected only modest numbers of native amphibian development stages (eggs or egg masses and larvae) in the permanent ponds. In contrast, numbers of the exotic American Bullfrogs, especially larvae, were prominent in the permanent ponds. Though post-metamorphic native amphibian richness in temporary ponds was low, native amphibians displayed heavy use of temporary ponds for reproduction.

All fishes in the Satsop pond complex were recorded exclusively in the three permanent ponds. The absence of fish and high prevalence of amphibians in the temporary ponds suggests an improvement in the quality of temporary pond habitat for amphibian reproduction. Besides amphibians and fishes, we recorded the presence of American Beaver actively using the ponds.

PHOTOPOINTS: To date, photopoint photographs have been taken on: 14 December 2016, Summer 2017, and quarterly thereafter resulting in a series of seasonal and pre-post restoration photos. **Figure 16** shows an example of photographs taken during this timeframe showing the changes in riparian vegetation, submerged large woody debris (LWD), wetland seasonal flooding, and wetland vegetation. For example, in Pond A we can see the LWD previously submerged, in Pond B we can see future wood recruitment from a fallen tree, and in Pond C we can see the extent of the seasonal flooding on the adjacent road in December (**Figure 16**). Photos will continue to be taken quarterly if possible. Post restoration comparisons for Pond B & C can be seen in **Figures 17 & 18**.



Figure 16. Representative photo-points for the three permanent ponds at the Satsop Ponds Restoration Site illustrating seasonal contrasts Pre-Restoration. Photos taken in late fall (14 December 2016) versus early summer (28 June 2017) show changes in water levels, riparian and wetland vegetation, and woody debris.



Figure 17. Representative pre-vs post-restoration photo-points at Pond C Restoration Site. Photos taken from same location show restoration efforts in 2019 involving shallowing of the pond edges and terrace steps vs original steep drop offs. Large woody debris is also seen post restoration around pond perimeter and in high water terraces



Figure 18. Representative pre-vs post-restoration photo-points at Pond B Restoration Site. Photos taken from same location show post restoration efforts in 2020 involving shallowing of the pond edges vs original steep drop offs. Large woody debris is also seen post restoration around pond perimeter and in high water terraces.

DISCUSSION

The Satsop Restoration Site pond complex contains all five native stillwater-breeding amphibian species that are known to reproduce in off-channel wetlands elsewhere within the Chehalis River floodplain. Besides these five species, we also found three juvenile Western Toads in the riparian area adjacent to Pond B in 2015 and 2016. This pattern agrees with what we have found elsewhere in the Chehalis floodplain. Western Toads are a Washington Species of Greatest Conservation Need and one of the nine non-fish species targeted in the ASRP. We have been unable to detect Western Toad breeding in the approximately 190 off-channel aquatic habitat sites (oxbows and wetlands) sampled over our 2015-2017 survey efforts. Rather, Western Toad breeding has been found to occur exclusively in the exposed (well-insolated) areas of large streams during their declining hydrographs when stillwater conditions suitable for breeding appear. The latter are primarily at least partly isolated habitat pockets possessing stillwater conditions, a Western Toad breeding site prerequisite: shallow non-isolated areas of the main channel may sometimes also be used if their flow is sufficiently low. Western Toads are known to breed along the Satsop River mainstem adjacent to the ponds, so the local pattern appears similar here and may be the source of the three juvenile Western Toads we found.

Overall breeding abundance of native amphibians in the permanent ponds seems low in comparison to many sites within the Chehalis floodplain, where dozens to hundreds of egg masses of Northwestern Salamanders, Northern Red-Legged Frogs, and other stillwater-breeding amphibians have been found. Low native amphibian production may reflect the influence of either biotic or abiotic factors. In the permanent ponds of the Satsop complex, these factors are most likely to originate from three things: exotic warm water species that are predators or competitors, habitat suitability that relates to pond structure, and native Roughskin newts that are seasonally important amphibian egg predators. We briefly discuss each.

The permanent ponds are rich in exotic warm water species. This exotic assemblage consists of at least eight species of fishes and the American Bullfrog. More importantly, three centrarchid fishes (Bluegill, Pumpkinseed and Rock Bass) dominate the exotic fish assemblage in all three ponds. Occupancy

modeling has clearly shown that centrarchid fishes significantly reduce the likelihood that several native amphibian species will be present (Holgerson et al. 2019), and data from a number of other sources suggest that centrarchid fishes pose a significant challenge for native amphibians (Hayes and Jennings 1986, Adams et al. 2003, Kiesecker and Blaustein 1998). Moreover, the combination of Centrarchid fishes and American Bullfrogs is particularly unfavorable for native amphibians because exotic fishes tend to prey on the pre-metamorphic life stages whereas the American bullfrog tends to prey on the post-metamorphic life stages (Hayes and Jennings 1986), and Centrarchid fishes can exacerbate the problem by reducing native predator numbers that could keep Bullfrogs densities low (Adams et al. 2003). Consequently, recruitment of native amphibians is challenging where the combination of Bullfrogs and Centrarchid fish combination of exotic species is present. Furthermore, beyond harm to native amphibians, exotic species are also likely to negatively impact native fishes, though these impacts are poorly understood in this regard. For example, juvenile Coho Salmon have been observed in the stomachs of centrarchid fishes elsewhere in the lower Chehalis system (D. Dick, pers. comm.), but the nature of this problem is unclear. Whether the restoration actions to increase hydrologic connection alters the exotic fish and Bullfrog populations is still to be seen and a focus of our ongoing Post-Restoration monitoring.

Limited numbers of native stillwater-breeding amphibians may also reflect the habitat quality of the permanent ponds at the Satsop Restoration Site. The permanent ponds were deep, generally steep-sided gravel pits dug in the 1970s that lack much of the shallow edge habitat and aquatic vegetation or braces for egg deposition and larval rearing needed by all five of native stillwater-breeding amphibians we recorded there. Such low emergent vegetation habitat is not only important for the breeding and rearing of native amphibians, it represents the suitable habitat critical for the Olympic Mudminnow, a Washington State sensitive fish species. Our restoration actions were tailored to create shallow shelves as potential habitat for native amphibian breeding and larval development. In addition, we planted emergent vegetation to add structure for egg braces. Whether these habitat alterations offset any impact exotic fish is still to be seen.

Beaver merit mention because of their ability to create habitat for both native amphibians and fishes. Beaver use of the Satsop Restoration Site was evident from their sign and workings in the permanent ponds and adjacent areas. However, beaver may be somewhat spatially limited due to the lack of extensive aquatic connections between water bodies. Lack of extensive aquatic connection forces beaver to engage in overland movement, which typically is associated with greater predation risk than movement through an exclusively aquatic pathway. Restoration removal of the spoils and dikes should facilitate easier movement pathways between the ponds, especially in winter with increased flows. How the beaver respond to those higher flows will be recorded in our ongoing surveys.

Temporary ponds currently provide a unique seasonal breeding and rearing habitat currently not available elsewhere within the Satsop Restoration Site pond complex. Long-Toed Salamanders and Pacific Treefrogs used these seasonally short-lived ponds heavily; both species are capable of developing through metamorphosis relatively rapidly (< 4 months) in low elevation habitats (Anderson 1967, Feaver 1971, Howard and Wallace 1985). Both species can also breed in the permanent ponds, but the temporary ponds are both typically aquatic predator free (especially of warmwater exotics) and likely have thermal regimes, especially during the day, that favor accelerated development. Hence, though opportunity exists for these two species to breed in the permanent ponds, their vulnerability to predation likely results in their higher densities in the temporary ponds. It also needs mention that several of the temporary ponds

were simply tire ruts in the local undeveloped road footprint. Lastly, though temporary ponds are generally inaccessible to fish, fish entry into temporary ponds may occur if the highwater events elevated water levels sufficiently. This is likely the pattern for the three native fishes we found in one temporary pond. Fishes that access a temporary pond may become trapped in that pond if water levels drop too quickly after the highwater event. Interestingly, a recent Post-Restoration high water event in 2021 connected all ponds (including temporary) to the adjacent river, thus providing ideal flood control (**Figure 10**).

NEXT STEPS

We collected multiple years of Pre-Restoration data that provide a sufficient baseline to assess how amphibian and fish species respond to Post-Restoration conditions. We anticipate that the improved connections between the Ponds and the Satsop River mainstem will shift physical conditions such that 1) the seasonal variation in stage will increase, 2) the seasonal thermal profile of the pond will decrease, and 3) seasonal dissolved oxygen variation in the pond will probably increase.

We suspect that the historic, relatively static conditions in the Satsop Restoration complex ponds with little variation in stage (except under extreme high water events), a warming seasonal temperature profile, and strong seasonal depression of dissolved oxygen strongly favored the suite of exotic water species currently present. Increased seasonal stage variation, as reflected in the difference between wet and dry years, has been shown to depress the population of the exotic American Bullfrog in the Eel River in California (S. Kupferberg, pers. comm.). Therefore, we expect the predicted shifts in physical conditions will depress populations of warmwater exotics occupying the Ponds and favor native species.

The general limitation of shallow breeding and rearing habitat was addressed in Phase 2 with the shallowing of Ponds B & C, planting of emergent vegetation, and the addition of several small ephemeral ponds within the swale between Ponds B & C. The upcoming two years of Post-Restoration monitoring, including at our “pseudo-reference” Pond A site where no restoration occurred directly in the pond, will verify whether our actions have improved connection for both Ponds.

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Appendix Table 1. Location and Bearings of Photopoints at Satsop Ponds Restoration Site. Bearings are listed by degrees where north = 0 and bearing direction is counted clockwise from north.

Pond	Photo Point			Bearings at which Photographs were taken																																							
	ID	Latitude	Longitude	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360			
A	A1	46.98484	-123.48718			X			X																									X			X			X			
	A2	46.98617	-123.48845															X			X			X			X			X			X			X			X				
	A3	46.98576	-123.48701									X			X			X			X			X			X			X													
B	B1	46.98698	-123.48682			X			X			X			X			X			X																				X		
	B2	46.98515	-123.48389		X			X			X			X			X			X			X			X			X			X				X			X				
	B3	46.98576	-123.48701			X			X			X			X			X			X			X			X			X			X			X			X			X	
C	C1	46.98635	-123.48244	X			X			X			X																							X			X				
	C2	46.98749	-123.48175																		X			X			X			X			X			X		X	X				
	C3	46.98706	123.48399	X			X				X			X			X			X			X			X			X			X				X			X				

Appendix Table 2. Pre-Restoration Species and Taxon Richness Summary for Amphibians at the Satsop Restoration Site in 2015-2019 Surveys by Water Year (October-September). Sampling did not capture the full 2014-2015 water year.

Taxa	Water Year	Species Occurrence and Richness								
		Permanent Ponds			Temporary Ponds					
		A	B	C	Dirt Mound	East	North	South	West	B pond Beaver
Native Amphibians										
Long-toed salamander	2014-2015	—	—	—	—	—	—	—	X	N/A
	2015-2016	—	X	—	X	X	X	—	X	N/A
	2016-2017	—	—	X	X	X	X	—	X	N/A
	2017-2018	—	—	—	X	X	X	—	X	X
	2018-2019	—	—	—	—	X	X	X	X	X

Northwestern salamander	2014-2015	X	X	X	—	—	—	—	—	N/A
	2015-2016	X	X	X	—	—	—	—	—	N/A
	2016-2017	—	X	—	—	—	—	—	—	N/A
	2017-2018	X	X	X	—	—	—	—	—	—
	2018-2019	X	—	X	—	—	—	—	—	—
Northern red-legged frog	2014-2015	X	X	X	—	—	—	—	—	N/A
	2015-2016	X	X	X	—	—	—	—	—	N/A
	2016-2017	X	—	X	—	—	—	—	—	N/A
	2017-2018	X	X	—	—	—	X	X	X	X
	2018-2019	X	—	X	—	—	—	—	—	—
Pacific treefrog	2014-2015	—	X	X	—	—	—	—	X	N/A
	2015-2016	—	X	—	—	—	X	—	—	N/A
	2016-2017	—	—	—	—	—	X	—	—	N/A
	2017-2018	X	—	—	—	X	X	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Roughskin newt	2014-2015	X	X	X	—	—	—	—	—	N/A
	2015-2016	X	X	X	—	—	—	—	—	N/A
	2016-2017	X	X	X	—	—	—	X	—	N/A
	2017-2018	X	X	X	—	—	—	—	—	—
	2018-2019	X	X	X	—	X	—	—	—	—
Western toad	2014-2015	—	X	—	—	—	—	—	—	N/A
	2015-2016	—	X	—	—	—	—	—	—	N/A
	2016-2017	—	—	—	—	—	—	—	—	N/A
	2017-2018	—	—	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Non-Native Amphibians										
American bullfrog	2014-2015	X	X	X	—	—	—	—	—	N/A
	2015-2016	X	X	X	—	—	—	—	—	N/A
	2016-2017	X	X	X	—	—	—	—	—	N/A

		2017-2018	X	X	X	—	—	—	—	—	—
		2018-2019	X	X	X	—	—	—	—	—	—
Grand Totals	Native	2014-2015	3	5	4	0	0	0	0	2	N/A
		2015-2016	3	6	3	1	1	2	0	1	N/A
		2016-2017	2	2	3	1	1	2	1	1	N/A
		2017-2018	4	3	2	1	2	3	1	2	2
		2018-2019	3	1	3	0	2	1	1	1	1
	Non-Native	2014-2015	1	1	1	0	0	0	0	0	N/A
		2015-2016	1	1	1	0	0	0	0	0	N/A
		2016-2017	1	1	1	0	0	0	0	0	N/A
		2017-2018	1	1	1	0	0	0	0	0	0
		2018-2019	1	1	1	0	0	0	0	0	0
	Overall	2014-2015	4	6	5	0	0	0	0	2	N/A
		2015-2016	4	7	4	1	1	2	0	1	N/A
		2016-2017	3	3	4	1	1	2	1	1	N/A
		2017-2018	5	4	3	1	2	3	1	2	2
		2018-2019	4	2	4	0	2	1	1	1	1

Appendix Table 3. Post-Restoration Species and Taxon Richness Summary for Amphibians of any Life Stage at the Satsop Restoration Site Surveys by Water Year (October-September). Water Year 2019 – 2020 includes an off-channel extensive survey conducted October 5-7, 2020 in order to maintain consistency with the number and type of surveys included in the Water Year. Water Year 2021-2022 is incomplete as it consists of three spring egg mass surveys and does not include the two off-channel extensive surveys planned for Summer and Fall 2021. N/A indicates the site was dry or no longer exists.

Taxa	Water Year	Species Occurrence and Richness										
		Permanent Ponds			Temporary Ponds							
		A	B	C	Dirt Mound 2	East	North	Tire rut South	Tire rut West	Beaver lodge rd.	Dirt Mound	Southwest pond B
Native Amphibians												
Long-toed salamander	2019-2020	—	—	—	—	X	X	—	X	X	—	—
	2020-2021	—	—	X	X	—	X	—	—	X	—	—
	2021-2022	—	—	—	—	X	X	—	X	—	X	—
Northwestern salamander	2019-2020	X	—	X	—	—	—	—	—	—	—	—
	2020-2021	X	X	X	X	—	—	—	—	—	—	—
	2021-2022	X	—	X	—	—	—	—	—	—	—	—
Northern red-legged frog	2019-2020	X	—	X	—	X	—	—	—	—	—	—
	2020-2021	—	—	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	X	—	—	—	—	—	—	—	—
Pacific treefrog	2019-2020	—	—	—	—	—	—	—	—	—	—	—
	2020-2021	—	X	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—	—	—
Roughskin newt	2019-2020	X	X	X	—	X	—	—	—	—	—	—
	2020-2021	X	X	X	X	—	—	—	—	—	—	—
	2021-2022	X	X	X	—	—	—	—	—	—	X	—
Western toad	2019-2020	—	—	—	—	—	—	—	—	—	—	—
	2020-2021	—	—	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—	—	—
Non-Native Amphibians												

American bullfrog		2019-2020	X	X	X	—	—	—	—	—	—	—	—
		2020-2021	X	X	X	X	—	—	—	—	X	—	—
		2021-2022	X	X	X	—	—	X	—	—	—	—	—
Grand Totals	Native	2019-2020	2	1	3	N/A	3	1	0	1	1	1	N/A
		2020-2021	3	3	4	3	N/A	1	N/A	N/A	1	0	N/A
		2021-2022	2	2	3	N/A	1	1	0	1	N/A	2	0
	Non-Native	2019-2020	1	1	1	N/A	0	0	0	0	0	0	N/A
		2020-2021	1	1	1	1	N/A	0	N/A	N/A	1	0	N/A
		2021-2022	1	1	1	N/A	0	1	0	0	N/A	0	0
	Overall	2019-2020	3	2	4	0	3	1	0	1	1	1	0
		2020-2021	4	4	5	4	N/A	1	N/A	N/A	2	0	0
		2021-2022	3	3	4	N/A	1	2	0	1	N/A	2	0

Appendix Table 4. Pre-Restoration Species Occurrence and Taxon Richness Summary for Native Fishes at the Satsop Restoration Site in 2015-2019 Surveys by Water Year (October-September). Sampling did not capture the full 2014-2015 water year. Red m-dashes — indicate that presence or lack of presence is uncertain because of species identity.

Taxa	Water Year	Species Occurrence and Richness								
		Permanent Ponds			Temporary Ponds					
		A	B	C	Dirt Mound	East	North	South	West	B Pond Beaver
Chum salmon	2014-2015	—	—	—	—	—	—	—	—	N/A
	2015-2016	X	—	—	—	—	—	X	—	N/A
	2016-2017	—	—	—	—	—	—	—	—	N/A
	2017-2018	—	—	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Largescale sucker	2014-2015	—	—	—	—	—	—	—	—	N/A
	2015-2016	X	X	X	—	—	—	—	—	N/A
	2016-2017	X	X	X	—	—	—	—	—	N/A
	2017-2018	—	X	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Northern pikeminnow	2014-2015	X	—	—	—	—	—	—	—	N/A
	2015-2016	X	X	X	—	—	—	X	—	N/A
	2016-2017	X	X	X	—	—	—	—	—	N/A
	2017-2018	X	X	—	—	—	—	—	—	—
	2018-2019	X	X	X	—	—	—	—	—	—
Olympic mudminnow	2014-2015	X	X	—	—	—	—	—	—	N/A
	2015-2016	X	X	—	—	—	—	—	—	N/A
	2016-2017	—	X	—	—	—	—	—	—	N/A
	2017-2018	—	X	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Pacific lamprey	2014-2015	—	—	—	—	—	—	—	—	N/A
	2015-2016	x	x	—	—	—	—	—	—	N/A

	2016-2017	X	—	X	—	—	—	—	—	N/A
	2017-2018	—	—	—	—	—	—	—	—	—
	2018-2019	X	—	—	—	—	—	—	—	—
Prickly sculpin	2014-2015	X	X	X	—	—	—	—	—	N/A
	2015-2016	X	X	X	—	—	—	—	—	N/A
	2016-2017	X	X	X	—	—	—	—	—	N/A
	2016-2017	—	—	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Rainbow/Steelhead trout	2014-2015	—	X	—	—	—	—	—	—	N/A
	2015-2016	—	—	—	—	—	—	—	—	N/A
	2016-2017	—	—	—	—	—	—	—	—	N/A
	2017-2018	—	—	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Redside shiner	2014-2015	—	—	—	—	—	—	—	—	N/A
	2015-2016	X	X	X	—	—	—	X	—	N/A
	2016-2017	X	X	—	—	—	—	—	—	N/A
	2017-2018	X	—	X	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Riffle/Reticulate sculpin	2014-2015	—	—	—	—	—	—	—	—	N/A
	2015-2016	X	X	—	—	—	—	—	—	N/A
	2016-2017	—	—	—	—	—	—	—	—	N/A
	2017-2018	—	—	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Speckled dace	2014-2015	X	—	—	—	—	—	—	—	N/A
	2015-2016	X	—	X	—	—	—	—	—	N/A
	2016-2017	X	—	—	—	—	—	—	—	N/A
	2017-2018	X	X	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—

Taxa	Water Year	Species Occurrence and Richness								
		Permanent Ponds			Temporary Ponds					
		A	B	C	Dirt Mound	East	North	South	West	B Pond Beaver
Three-spined stickleback	2014-2015	X	X	X	—	—	—	—	—	N/A
	2015-2016	X	—	—	—	—	—	—	—	N/A
	2016-2017	X	X	—	—	—	—	—	—	N/A
	2017-2018	X	X	X	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Torrent sculpin	2014-2015	—	X	X	—	—	—	—	—	N/A
	2015-2016	—	X	—	—	—	—	—	—	N/A
	2016-2017	—	—	—	—	—	—	—	—	N/A
	2017-2018	—	—	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Totals	2014-2015	5	5	3	0	0	0	0	0	N/A
	2015-2016	10	8	5	0	0	0	3	0	N/A
	2016-2017	6	6	4	0	0	0	0	0	N/A
	2017-2018	4	5	1	0	0	0	0	0	0
	2018-2019	3	3	3	0	0	0	0	0	0

Table 5. Post-Restoration Species Occurrence and Taxon Richness Summary for Native Fishes at the Satsop Restoration Site Surveys by Water Year (October-September). Water Year 2019 – 2020 includes an off-channel extensive survey conducted October 5-7, 2020 in order to maintain consistency with number and type of survey included in the Water Year 2021-2022 is incomplete as it consists of three spring egg mass surveys and does not include the two off-channel extensive surveys planned for Summer and Fall 2021.

Taxa	Water Year	Species Occurrence and Richness								
		Permanent Ponds			Temporary Ponds					
		A	B	C	Dirt Mound	East	North	South	West	Dirt Mound 2
Chum salmon	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—
Coho Salmon	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	X	—	—	—	—	—	—	—
	2021-2022	—	X	—	—	—	—	—	—	—
Lamprey Spp	2019-2020	X	—	X	—	—	—	—	—	—
	2020-2021	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—
Northern pikeminnow	2019-2020	X	X	X	—	—	—	—	—	—
	2020-2021	X	X		—	—	—	—	—	—
	2021-2022	X	X	X	—	—	—	—	—	—
Largescale sucker	2019-2020	—	—	X	—	—	—	—	—	—
	2020-2021	X	X	X	—	—	—	—	—	—
	2021-2022	X	X	X	—	—	—	—	—	—
Olympic mudminnow	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—
Rainbow/Steelhead trout	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	—	—	—	—	—	—	—	—

	2021-2022	—	—	—	—	—	—	—	—	—
Redside shiner	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	X	X	—	—	—	—	—	—
	2021-2022	X	X	X	—	—	—	—	—	—
Sculpin Spp.	2019-2020	X	X	X	—	—	—	—	—	—
	2020-2021	X	X	X	—	—	—	—	—	—
	2021-2022	X	X	X	—	—	—	—	—	—
Speckled dace	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	X	X	—	—	—	—	—	—
	2021-2022	—	X	X	—	—	—	—	—	—
Three-spined stickleback	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	X	—	—	—	—	—	—	—
	2021-2022	—	X	X	—	—	—	—	—	—
Totals	2019-2020	3	2	4	0	0	0	0	0	0
	2020-2021	3	7	4	0	0	0	0	0	0
	2021-2022	5	7	6	0	0	0	0	0	0

Table 6. Pre-Restoration Species Occurrence and Taxon Richness Summary for Non-Native Fishes at the Satsop Restoration Site in 2015-2019 Surveys by Water Year (October-September). Sampling did not capture the full 2014-2015 water year. Red m-dashes — indicate that presence or lack of presence is uncertain because of species identification.

Taxa	Water Year	Species Occurrence and Richness								
		Permanent Ponds			Temporary Ponds					
		A	B	C	Dirt Mound	East	North	South	West	B Pond Beaver
Black Crappie	2014-2015	—	—	—	—	—	—	—	—	N/A
	2015-2016	—	—	x	—	—	—	—	—	N/A
	2016-2017	—	—	—	—	—	—	—	—	N/A
	2017-2018	—	x	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Bluegill	2014-2015	x	x	x	—	—	—	—	—	N/A
	2015-2016	x	x	x	—	—	—	—	—	N/A
	2016-2017	x	x	x	—	—	—	—	—	N/A
	2017-2018	x	x	x	—	—	—	—	—	—
	2018-2019	x	x	x	—	—	—	—	—	—
Brown Bullhead	2014-2015	x	—	—	—	—	—	—	—	N/A
	2015-2016	x	—	—	—	—	—	—	—	N/A
	2016-2017	x	—	—	—	—	—	—	—	N/A
	2017-2018	x	—	—	—	—	—	—	—	—
	2018-2019	x	—	x	—	—	—	—	—	—
Common Carp	2014-2015	—	—	—	—	—	—	—	—	N/A
	2015-2016	—	—	—	—	—	—	—	—	N/A
	2016-2017	—	x	—	—	—	—	—	—	N/A
	2017-2018	—	—	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Largemouth Bass	2014-2015	—	—	—	—	—	—	—	—	N/A
	2015-2016	—	—	—	—	—	—	—	—	N/A

	2016-2017	—	—	x	—	—	—	—	—	N/A
	2017-2018	—	—	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Pumpkinseed	2014-2015	x	—	x	—	—	—	—	—	N/A
	2015-2016	x	x	x	—	—	—	—	—	N/A
	2016-2017	x	—	x	—	—	—	—	—	N/A
	2017-2018	x	—	—	—	—	—	—	—	—
	2018-2019	x	—	—	—	—	—	—	—	—
Rock Bass	2014-2015	—	x	x	—	—	—	—	—	N/A
	2015-2016	x	x	x	—	—	—	—	—	N/A
	2016-2017	—	x	—	—	—	—	—	—	N/A
	2017-2018	x	x	x	—	—	—	—	—	—
	2018-2019	—	x	x	—	—	—	—	—	—
Yellow Perch	2014-2015	—	—	—	—	—	—	—	—	N/A
	2015-2016	—	x	—	—	—	—	—	—	N/A
	2016-2017	—	—	—	—	—	—	—	—	N/A
	2017-2018	—	—	—	—	—	—	—	—	—
	2018-2019	—	—	—	—	—	—	—	—	—
Totals	2014-2015	3	2	3	0	0	0	0	0	N/A
	2015-2016	4	4	4	0	0	0	0	0	N/A
	2016-2017	3	3	3	0	0	0	0	0	N/A
	2017-2018	4	3	2	0	0	0	0	0	0
	2018-2019	3	2	3	0	0	0	0	0	0

Table 7. Post-Restoration Species Occurrence and Taxon Richness Summary for Non-Native Fishes at the Satsop Restoration Site Surveys by Water Year (October-September). Water Year 2021-2022 is incomplete as it consists of three spring egg mass surveys and does not include the two off-channel extensive surveys planned for Summer and Fall 2021.

Taxa	Water Year	Species Occurrence and Richness								
		Permanent Ponds			Temporary Ponds					
		A	B	C	Dirt Mound	East	North	South	West	Dirt Mound 2
Black Crappie	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—
Bluegill	2019-2020	X	X	X	—	—	—	—	—	—
	2020-2021	X	X	X	—	—	—	—	—	—
	2021-2022	X	X	X	—	—	—	—	—	—
Brown Bullhead	2019-2020	X	—	X	—	—	—	—	—	—
	2020-2021	X	X	—	—	—	—	—	—	—
	2021-2022	—	—	X	—	—	—	—	—	—
Common Carp	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—
Largemouth Bass	2019-2020	—	—	—	—	—	—	—	—	—
	2020-2021	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—
Pumpkinseed	2019-2020	X	—	X	—	—	—	—	—	—
	2020-2021	—	X	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—
Rock Bass	2019-2020	—	X	X	—	—	—	—	—	—
	2020-2021	—	X	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—
Yellow Perch	2019-2020	—	—	—	—	—	—	—	—	—

	2020-2021	—	—	—	—	—	—	—	—	—
	2021-2022	—	—	—	—	—	—	—	—	—
Totals	2019-2020	3	2	4	0	0	0	0	0	0
	2020-2021	2	4	1	0	0	0	0	0	0
	2021-2022	1	1	2	0	0	0	0	0	0

Supplemental Study - Lower Satsop River Snorkel Survey Summary

Nicholas Wegener

Methods: From 13:00 through 16:00 on 14 September 2016, four Washington Department of Fish & Wildlife scientific technicians (Nicholas P. Wegener - team lead [NPW], Kelly R. Perry [KRP], David R. Snyder [DRS], and Noll E. Steinweg [NES]) surveyed four contiguous reaches of the Satsop River from Hwy 12 downstream over a distance of approximately 2 miles to Fadden Road on the east bank (**Appendix Figure 1**). Each reach was approximately a half mile long. We entered the river from a boat ramp on the east bank of the river just downstream of the Hwy 12 Bridge. Surveying downstream, surveyors lined up perpendicular to the river such that each individual surveyed roughly one quarter of the river width. We surveyed the entire wetted width except for riffles too shallow to survey. Each surveyor recorded data on waterproof paper. Survey reach breaks were chosen from easily recognizable features that allowed surveyors to find them while in the field with only a paper map and no GPS assistance.

Besides recording aquatic species, we also noted important habitat features across the survey area, which were: instream woody debris, rip-rap bank stabilization, lack of tree and shrub canopy in the riparian area, and bank incision and sloughing.

Results: We observed an estimated 5,814 individual fish representing at least eight different species (**Appendix Table 8**); No amphibians were observed. Overall, most (97.1%) of the fish assemblage was represented by four species: Three-spined Stickleback, Speckled Dace, Redside Shiner, and Largescale Sucker. Redside shiner, the most abundant species overall, represented 41.4% of the total.

The four reaches varied in their abundance and diversity of fishes and in habitat complexity.

Reach 1, the upstream-most reach (**Appendix Figure 1**), had the greatest relative abundance ($n = 3389$) and tied for the greatest species richness (at least 8; **Appendix Table 8**). In this reach, we observed a dozen pool/riffle dyads, and jams with woody debris scattered throughout, including several large debris jams containing very large (≥ 1 m) woody debris. A 50+-meter long debris jam along the east bank created diverse micro habitats within the wetted channel. We noticed a strong association existed between structural elements like woody debris and where fish were observed. In and among the 50+-m debris jam, we found large schools of Three-spined Stickleback (over 900 total fish) and two adult Chinook Salmon. In contrast, relatively few Three-spined Stickleback ($n = 36$) were observed in the other three reaches combined. Redside Shiner, which were schooling in groups of 50-150, was the most frequently observed fish ($n = 1,030$) observed in this reach and throughout the survey ($n = 2,422$). Largescale Sucker was the third most frequently observed fish in this reach ($n = 721$), and were the second most frequently observed fish in the survey ($n = 1,164$; **Appendix Table 8**). We recorded adult Suckers primarily along the bottom of the river in areas with little or no cover, whereas smaller suckers were observed amongst woody debris. Speckled Dace was both the fourth most frequently observed species overall ($n =$

1,109) and fourth most frequently observed in this reach. Over 95% of Speckled Dace ($n = 1,088$) were recorded in Reaches 1 and 2.

Remaining species in Reach 1 were recorded in much lower numbers (≤ 33). Trout species were observed in several different age classes. One Steelhead in its silver smolt livery was observed as well as a several large cutthroat trout. Around 30 smaller, difficult-to-identify trout were also observed. Commonly found among other fish species, trout tended not to be observed with other trout. A modest number of Pikeminnow ($n = 20$) were observed in Reaches 1 and 2.

Reach 2 (**Appendix Figure 1**) maintained a diverse hydrological profile with similar numbers of pool/riffle dyads to Reach 1 but also one or two long runs with uniform substrate that were nearly void of any fish. There was also a 15-m section of rip rap on the east bank at the upstream end of Reach 2 that created a pool that was approximately 8 m deep. This is 3-4 times deeper than the estimated average pool depth. Reach 2 had a fish species richness similar to that of Reach 1 but with a slightly different species composition and fish numbers were generally lower; much lower in some cases, e.g., 947 Three-spined stickleback in Reach 1 but only 10 in Reach 2. Redside Shiner numbers were similar to Reach 1 ($n = 1,030$). Speckled Dace numbers were higher in Reach 1 ($n=628$) compared to Reach 2 ($n=460$). Largescale Sucker numbers decreased from 721 in Reach 1 to 131 in Reach 2. Trout numbers dropped from 33 in Reach 1 to 28 in Reach 2. This reach also had three sculpins that were not identified to species. Although not identified to species, five adult salmon were observed in the aforementioned pool. These were likely Chinook as two other adult Chinook were observed in Reach 1. Two observers, NPW and NES, also observed what appeared to be a type of sucker in this reach that was taller than normal and had large black spots similar in appearance to parr marks.

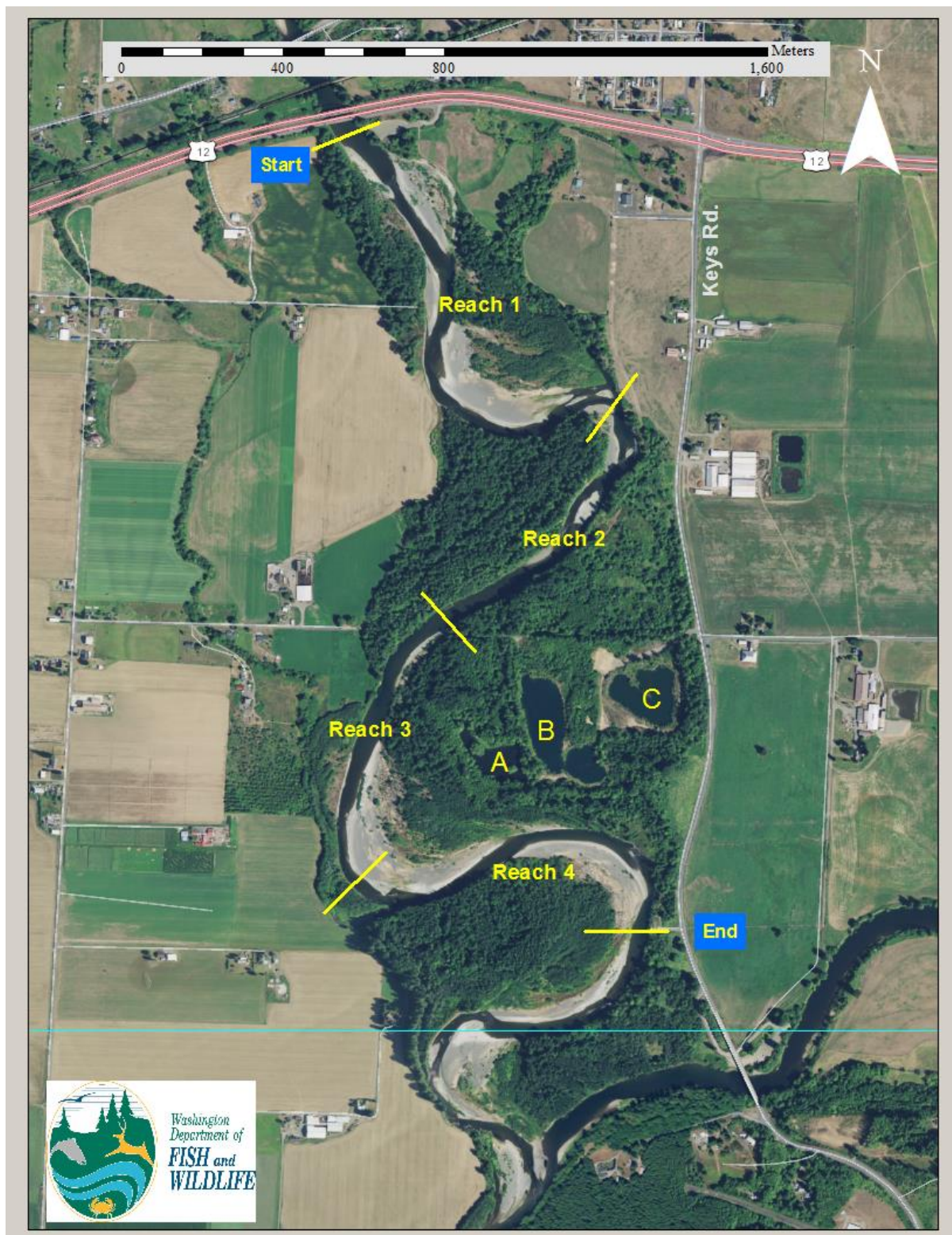
Reach 3 was relatively uniform and consisted mostly of runs and a homogeneous riparian area for several hundred meters. An occasional debris jam was present in which most of the fish were observed. This stretch exhibited the largest amount of bank incision and sloughing; few fish were observed in these areas. Large stretches also existed where no trees or other bank stabilizing plants were present. Whether riverine processes, agriculture or both impacted the west bank of this reach is unclear. Overall fish numbers and richness in Reach 3 (**Appendix Figure 1**) dropped dramatically with only Redside shiner and Largescale sucker being recorded in any significant numbers (**Appendix Table 8**). This reach had 280 Redside Shiner, 230 Largescale Sucker, 26 Three-spined Stickleback, and 9 unidentified trout. Similar to Reach 2, three sculpins were also observed in this reach. Two of these sculpins were observed incidentally while one surveyor was taking a break and saw them while looking down into the water. Thirty-five Western Pearlshell Mussels were observed in this reach.

At its upstream end, Reach 4 (**Figure 1**) had similar problems of bank instability but quickly transitioned into a more complex and less altered stretch. Riparian areas were dominated by alder and cottonwood, stream sinuosity increased, and the stream cross-section diversified with more slow-moving shallow areas and deeper areas of scour than Reach 3. Debris jams, which were

smaller and more infrequent in Reach 3, increased in frequency but no large debris jams like those observed in Reaches 1 and 2 were present. However, this seemingly high quality habitat did not translate into greater fish richness or abundance. Only 190 fishes were observed in this reach (**Appendix Table 8**), giving it the lowest relative abundance among the four reaches. Eighty-two of each of suckers and shiners, 21 dace, three unidentified trout, and two pikeminnow were observed in this reach.

Appendix Table 1: Fish species and numbers observed while performing the 14 September 2016 snorkel survey in the Lower Satsop River.

Fish Species Observed		Reach 1	Reach 2	Reach 3	Reach 4	Totals
CAMA	Largescale Sucker	721	131	230	82	1164
GAAC	Three-spined stickleback	947	10	26	0	983
ONTS	Chinook Salmon	2	0	0	0	2
ONMY	Steelhead/Rainbow Trout	5	0	0	0	5
ONCL	Cutthroat Trout	2	0	0	0	2
PTOR	Northern Pikeminnow	20	20	0	2	42
RHOS	Speckled Dace	628	460	0	21	1109
RIBA	Redside Shiner	1030	1030	280	82	2422
UNSA	UK Salmonid	1	5	0	0	6
UNTR	UK Trout sp.	33	28	9	3	73
UNSC	Sculpin spp.	0	3	3	0	6
Reach (Grand) Totals		3389	1687	548	190	5814



Appendix Figure 1: Lower Satsop River reaches 1-4 of the Snorkel Survey performed on 14 September 2016. Satsop Ponds (A, B, and C) are also labeled.